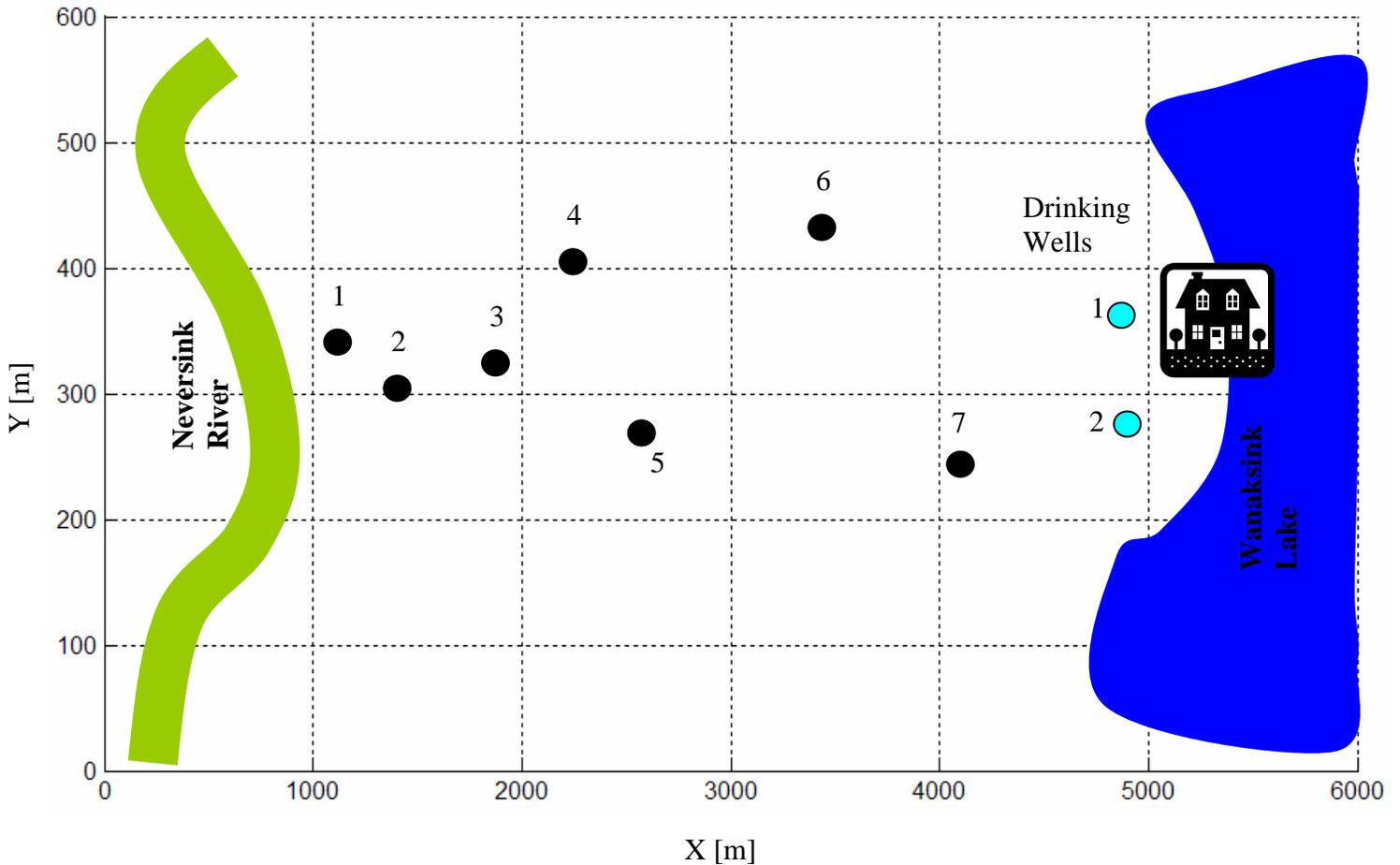
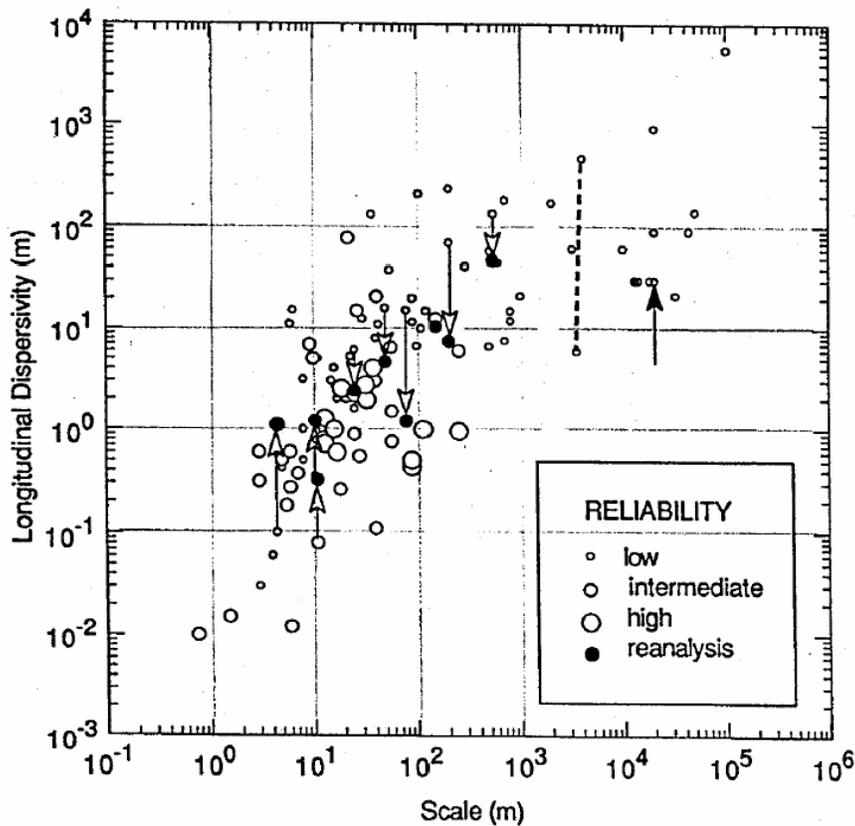


(1) About three and one-half years ago, Rutch’s Tavern in Dock Hill New York dumped a secret chemical into the Neversink River. The name of this chemical cannot be released for legal reasons but it has an intoxicating effect and is not suitable for pregnant women, children, or anyone needing to drive to work or operate heavy machinery. Hence there is concern that it may reach drinking wells near Wanaksink Lake. To help track the chemical plume, 7 monitoring wells were installed approximately 3 and one-half years ago. Head values in these wells have been fairly constant over the past three and one-half years. However, a recent increase in hurricanes has affected the hydrology of the region, and measurements suggest that the head values have changed. Right before the hurricanes, the chemical was found near its solubility of 100 mg/l in monitoring wells 1-5, but there was no trace of the chemical in wells 6 or 7. Seward consulting (the local consulting firm), has collected other useful data: the aquifer has bulk density of 1.8 g/cm<sup>3</sup>, and a porosity of 0.3, and the chemical has a partition coefficient of 0.25 l/kg (you may assume equilibrium sorption). Unfortunately, some of the chemical entered the consulting firm’s drinking water supply and they were unable to take measurements of hydraulic conductivity and no longer have the mental capacity to work on the problem. Being MIT students, you’ve been put on the spot to estimate hydraulic conductivity based on the given information and to estimate how long it will take until the concentration will take to reach an intoxicating level of 10 mg/l in the drinking wells. The time to reach an intoxicating level is needed before any remedial action can take place (60 points).



Head [m]	River	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7
3.5 years ago to start of hurricanes	153.17	150.34	151.05	144.52	142.13	141.37	139.35	137.29
Present	156.85	158.55	155.7	144.78	139.99	135.85	133.37	128.25

Some other useful information follows. A good plot from Gelhar *et al.*, 1992 for estimating dispersivity is shown below (don't worry about the reliability):

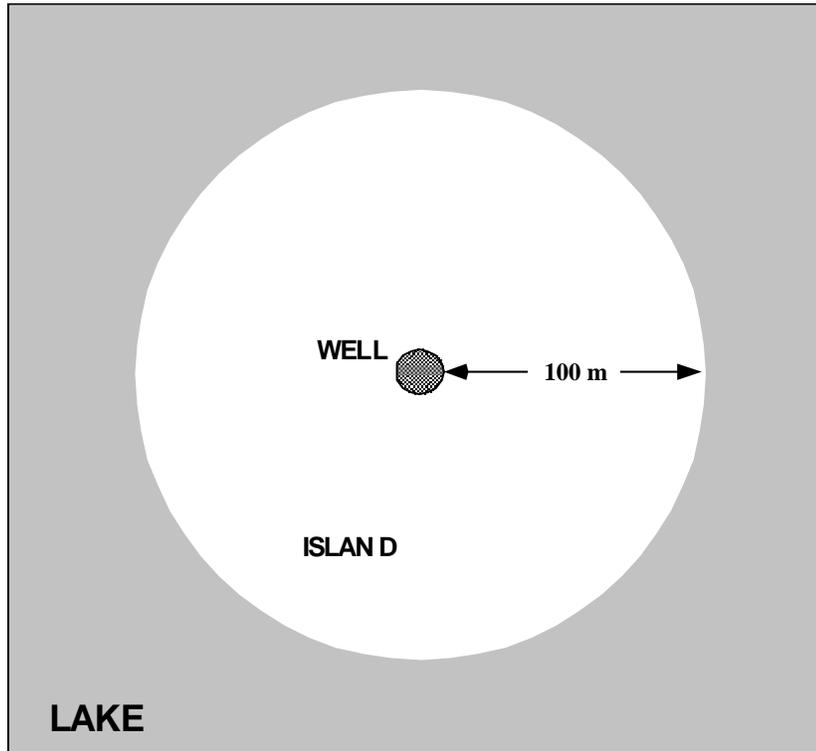


An approximate solution to the advection dispersion for a constant solute flux with initial concentration  $C_0$  with a 0 concentration for a remote boundary is:

$$C = \frac{C_0}{2} \operatorname{erfc} \left[ \frac{x - vt}{2\sqrt{Dt}} \right]$$

Where  $\operatorname{erfc}$  is the complementary error function,  $x$  is the spatial distance,  $v$  is the mean velocity of the solute,  $D$  is the dispersion coefficient, and  $t$  is time.

(2) The diagram below shows a confined, homogeneous, and isotropic aquifer beneath a circular island of radius 100 m in a lake. A pumping well is located in the middle of the island. Flow is steady state. In the picture below the hatched circle in the middle is the well, which is fully screened across the entire aquifer. Flow is horizontal to the well. The confined aquifer is 8 m thick. The extraction rate is  $75.4 \text{ m}^3/\text{day}$ . The hydraulic conductivity of the aquifer is  $30 \text{ m/day}$ . The porosity is  $0.3$ . Assume no flow through the confining layer and steady-state conditions.



**(a)** What is the gradient of hydraulic head at the edge of the island? Assume no flow through the confining layer and steady-state conditions. *(10 points)*

**(b)** The lake contains  $1 \mu\text{g/L}$  bromide (not enough to significantly change the density). Bromide is a conservative tracer (i.e. no chemical reaction, or sorption), and does not exist in the groundwater before pumping. If we assume that both diffusion and dispersion are negligible how long does it take for the bromide to reach the well after pumping commences? Still assume steady state. *(10 points)*

(c) The lake also contains  $1 \mu\text{g/L}$  lithium. Lithium sorption may be accurately modeled with a linear equilibrium isotherm. From a line of sampling wells you determine that just when the bromide reaches the pumping well, the lithium has traveled only 29.3 m from the edge of the island towards the pumping well. What is the retardation factor for lithium? (10 points)

(d) Plot the breakthrough curves at the well for bromide and lithium. Also show a breakthrough curve for bromide when dispersion occurs. Is the breakthrough time of  $0.9 \mu\text{g/L}$  and  $0.1 \mu\text{g/L}$  of bromide increased or decreased compared to the arrival time of the solute front with no dispersion? (10 points)